

Research Topics in Aerospace

Ulrich Schumann *Editor*

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Atmospheric Physics

Background—Methods—Trends



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Ulrich Schumann
Editor

Atmospheric Physics

Background—Methods—Trends

Editor

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Preface

The Institute of Atmospheric Physics (Institut für Physik der Atmosphäre, IPA) of the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, DLR) in Oberpfaffenhofen near Munich, Germany was founded on 1 July 1962. This book appears on the occasion of the 50th anniversary of this institute. The book is part of the DLR-Springer Series, Research Topics in Aerospace, and as such addresses topics of relevance to aviation, Earth observation from Space, and further research and development fields of DLR including mobility and renewable energy. The book covers topics of special expertise in this institute.

The book is structured into three main sections dealing with general aspects of the atmosphere, methods and instruments used for research in this field, and topics and trends of major importance for present and ongoing research. Each section contains several chapters, in total 51. They cover specific topics, written by experts of this institute and partner institutes. Most of the external authors are former staff members of this institute. Several external authors are now members of the meteorological institute (MIM) of the Ludwig-Maximilians-University (LMU) with which IPA has a long tradition of cooperation and now an institutional link. Each chapter briefly describes the general knowledge in the field, and then explains in detail results obtained by the various teams represented by the authors. A few remarks in the chapters illuminate the historical development of the research topics in this field. The basic *keywords* (printed in italic) of importance in this field are defined in chapters identified by a list of keywords at the end of the book. The references cited refer to important publications of relevance for the field of research discussed, but most of the references refer to work performed in this institute.

The authors intended to describe their field in a manner understandable to a wide community of readers with little reference to background literature. We hope we succeeded and that the book is of interest and help to all who are related to aspects of atmospheric physics—scientific, institutional, educational or in cooperation.

The Institute of Atmospheric Physics has a long tradition in research on meteorology and atmospheric physics in relation to aerospace. It was formed from institutional roots going back to the Rhön-Rossitten society in the year 1924. It has kept its dedication and original name without changes over the last 50 years. Further details can be found in the final chapter.



The staff members of the Institute of Atmospheric Physics of DLR in Oberpfaffenhofen in January 2012 (Photo by Karl-Heinz Koos and Hans Volkert)

At present, the institute performs research on the physical and chemical processes of the troposphere and stratosphere. The knowledge of dynamical, cloud physical, and chemical processes constitutes the basis for many applications of aviation, Earth observation, mobility and renewable energy. On regional and global scales the relevant processes and changes of the state of the atmosphere are quantified and systematically investigated using remote sensing, research aircraft, and computational models. Example research topics include the impact of aviation and other modes of transport on climate, and the development of new measurement techniques for future satellite missions. The institute has access to the major research facilities of the DLR, including the research aircraft Falcon and HALO.

The institute is grateful to all the support it received over the decades from DLR management and cooperating institutes and facilities. We acknowledge the fruitful cooperation with many external partners, and thank for the support provided by Bavarian and Federal ministries, European and international funding partners, scientific societies, and for cooperation with industry.

It is my pleasure to take this occasion to thank all authors for their contributions. About 50 internal and several external reviewers helped essentially to improve the various contributions. Dietrich Heimann coordinated the reviews and helped in finding solutions of all kinds. Nadja Reimann and Sonja Mandelartz kept track of all contributions and formatted many of the lists of references. Reinhold Busen completed the list of abbreviations. Winfried Beer managed the data processing tasks. In particular I thank the lector, Susan Giegerich, for her professional work on the manuscripts in short time. Finally we thank the Springer Verlag for final preparation and publishing this book.

The institute gratefully acknowledges the pioneering work of the former directors of predecessors, Walter Georgii and Harald Koschmieder. Moreover we thank the founder of this institute, Hans Gerhard Müller (director from 1962 to 1972) and the former directors of IPA, Heinz Fortak (1973–1976) and Manfred

Reinhardt (1974–1992), for their pioneering work. I myself had responsibility for this institute since 1982, first jointly with Manfred Reinhardt, and alone since 1992. The institute is presently structured into five departments. The departments and their leaders are as follows: Atmospheric Dynamics (Robert Sausen), Atmospheric Trace Species (Hans Schlager), Atmospheric Remote Sensing (Ralf Meerkötter and Bernhard Mayer, LMU), Cloud Physics and Traffic Meteorology (Thomas Gerz in cooperation with George Craig, LMU) and Lidar (Gerhard Ehret). In spring 2012, the institute had about 125 staff members, most of them can be seen on the photo. I am grateful to all who supported this institute over the years. Finally I wish the readers of this book enjoyable and enlightening reading.

Oberpfaffenhofen, Germany, 1 April 2012

Ulrich Schumann

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Abbreviations

3MI	Multi-viewing multi-channel multi-polarization imager
A2D	ALADIN airborne demonstrator
AATSR	Advanced along-track scanning radiometer
ABI	Advanced baseline imager
ABL	Atmospheric boundary layer
ACARE	Advisory council for aeronautics research in Europe
ACCESS	Arctic climate change economy and society
ACE	Atmospheric chemistry experiment
ACTA	Automatic contrail tracking algorithm
ADM-Aeolus	Atmospheric dynamics mission-Aeolus
ADWICE	Advanced diagnosis and warning system for aircraft icing environments
AerCARE	Impacts of aerosol layers on atmosphere and climate
AERO2k	Global aviation emissions inventory
AERONOX	Impact of NO _x emissions from aircraft on the atmosphere
AEROTROP	Impact of aircraft emissions on the heterogeneous chemistry of the tropopause region
AIC	Aviation induced cloudiness
AIMES	Analysis, integration and modeling of the Earth system
AIMS	Atmospheric chemical ionization mass spectrometer
AIRS	Atmospheric infrared sounder
ALADIN	Atmospheric laser Doppler instrument
ALEX-F	Airborne aerosol Lidar experiment
ALEXIS	Mie backscatter lidar (Phase A study)
AMAN	Arrival manager
AMDAR	Aircraft meteorological data relay
AMMA	African monsoon multidisciplinary analysis
AMS	Aerodyne mass spectrometer
Amu	Atomic mass units
AOCS	Attitude and orbit control system
AOD	Aerosol optical depth

AOGCM	Atmosphere-ocean general circulation models
APICS	Algorithm for the physical investigation of clouds with SEVIRI
APOLLO	AVHRR processing scheme over clouds, land and ocean
A-SCOPE	Advanced space carbon and climate observation of planet Earth
ASTAR	Spring-time transport of pollutants into the Arctic
ATC	Air traffic control
ATLID	Atmospheric Lidar
ATM	Air traffic management
ATR	Average temperature response
A-Train	Afternoon train (a NASA satellite constellation)
A-TReC	Atlantic THORPEX regional campaigns
ATSR-2	Along-track scanning radiometer
ATTAS	Advanced technologies testing aircraft system
ATTICA	European assessment of transport impacts on climate change and ozone depletion
AVA	Aerodynamische Versuchsanstalt
AVAPS	Airborne vertical atmospheric profiling system
AVHRR	Advanced very high resolution radiometer
AVOSS	Aircraft vortex spacing system
BAHAMAS	Basic HALO measurement and sensor system
BBR	Broad band radiometer
BC	Black carbon
BMBF	(German) Federal ministry of education and research
BMVBS	Federal ministry for traffic, construction and urban development
BTD	Brightness temperature difference
C4MIP	Coupled climate-carbon cycle model intercomparison project
CALIOP	Cloud-aerosol lidar with orthogonal polarization
CALIPSO	Cloud-aerosol lidar and infrared pathfinder satellite observations
CAPE	Convective available potential energy
CARIBIC	Civil aircraft for the regular investigation of the atmosphere based on an instrument container
CAS-DPOL	Cloud and aerosol spectrometer
CASI	Compact airborne spectrographic imager
CATS	Climate-compatible air transportation system
CBL	Convective boundary layer
Cb-TRAM	Cumulonimbus tracking and monitoring
CCD	Charge-coupled device
CCM	Chemistry climate model
CCMVal	Chemistry-climate model validation
CCN	Cloud condensation nuclei
CDA	Contrail detection algorithm

CDC	Collision dissociation chamber
CERES	Clouds and the Earth radiant energy system
CFC	Chlorofluorocarbons
CFH	Cryogenic frost point hygrometer
CFL	Courant-Friedrichs-Lewy criterion
CG	Cloud-to-ground
CHARM®	CH ₄ airborne remote monitoring
CI	Chemical ionization
CIMS	Chemical ionization mass spectrometry
CIN	Convective inhibition energy
CIP	Cloud imaging probe
CoTTCAT	Cambridge tropospheric trajectory model of chemistry and transport
CIWSIR	Cloud ice water submillimeter imaging radiometer
CLEOPATRA	Cloud experiment Oberpfaffenhofen and transports
CMD	Count median diameter
CMIP5	Coupled model intercomparison project
CN	Condensation nuclei
CNES	Centre national d'Etudes Spatiales
CNRS	National center for scientific research, France
CoCiP	Contrail cirrus prediction model
COCS	Cirrus optical properties derived from CALIOP and SEVIRI
CONCERT	Contrail and cirrus experiment
CONTRACE	Convective transport of trace gases into the middle and upper troposphere over Europe: budget and impact on chemistry
COPS	Convective and orographically-induced precipitation study
COSMO	Consortium for small-scale modeling, NWP model of DWD
COST	European cooperation in science and technology
CPC	Condensation particle counter
CPI	Cloud particle imager
CPR	Cloud profiling radar
CPU	Central processing units
CRDS	Cavity ring-down spectroscopy
CRPSS	Conditional ranked probability skill score
CRS	Cloud resolving simulation
CS	Calibration source
CTBTO	Comprehensive nuclear-test-ban treaty organization
CTH	Cloud-top-height
CW	Continuous-wave
D2P	Deterministic two-phase wake vortex model
DAOD	Differential atmospheric optical depth
DE	Detection efficiency
DE	Deutschland (Germany)
DERA	Defence evaluation and research agency, UK

DFD	Deutsches Fernerkundungsdatenzentrum, DLR Oberpfaffenhofen
DFG	Deutsche Forschungsgemeinschaft
DFS	Deutsche Forschungsanstalt für Segelflug
DFS	Deutsche Flugsicherung (German Air Traffic Control)
DFVLR	Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt
DGVM	Dynamic global vegetation models
DIAL	Differential absorption lidar
DLH	Deutsche Lufthansa AG
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German aerospace center)
DMA	Differential mobility analyzer
DMPS	Differential mobility particle sizer
DMS	Dimethylsulfide
DMT	Droplet measurement technologies, Boulder CO, USA
DNS	Direct numerical simulation
DOA	Approved design organization
DOAS	Differential optical absorption spectroscopy
DOC	Direct operating costs
DU	Dobson units
DVL	Deutsche Versuchsanstalt für Luft- und Raumfahrt
DWD	Deutscher Wetterdienst / German meteorological service
DWL	Doppler wind lidar
EADS	European aeronautic defense and space company
EARLINET	European aerosol research lidar network
EarthCARE	Earth clouds, aerosols and radiation explorer
EC	European commission
ECHAM5	ECMWF and Hamburg version 5 of an atmospheric GCM
ECMWF	European centre for medium-range weather forecasts
EC-TRAM	Electrically-charged cells tracking and monitoring
ECV	Essential climate variables
EF	Energy forcing
ELITE	European contribution to LITE
EMAC	ECHAM/MESSy atmospheric chemistry model
ENIAC	Electronic numerical integrator and computer
ENSO	El-Niño southern oscillation
ENVISAT	Environmental multi instrument satellite (launched 2002)
EOS	Earth observing system
EPS	Ensemble prediction system
ERBE	Earth radiation budget experiment
ERBS	Earth radiation budget satellite
ESA	European space agency
ESM	Earth system model
ESMVal	Earth system model validation

ESRIN	European space research institute
ETH	Swiss federal institute of technology Zurich
EU	European union
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
EUCAARI	European integrated project on aerosol, cloud, climate, and air quality interactions
EUFAR	European facility for airborne research
EULAG	Eulerian/semi-lagrangian numerical model for fluids
EULINOX	European lightning nitrogen oxides experiment
EUMETSAT	European organisation for the exploitation of meteorological satellites
EUROCONTROL	European air traffic management centre
EUPHORE	European photoreactor
EUPLEX	European polar stratospheric cloud and lee-wave experiment
EURASER	European research aircraft and sensors for environmental research
EXPORT	European export of precursors and ozone by long-range transport
FAA	Federal aviation administration
FAAM	Facility for airborne atmospheric measurements
FACE	Free atmospheric CO ₂ enrichment
FAR	False alarm ratio, false alarm rate
FBI	Frequency bias index
FCI	Flexible combined imager
FFM	Flugwissenschaftliche Forschungsanstalt München
FIONA	Formal intercomparisons of observations of nitrous acid
FMG	Flughafen München GmbH
FSC	Fuel sulfur content
FSSP	Forward scattering spectrometer probe
FU Berlin	Freie Universität Berlin
FWHM	Full-width at half-maximum
FZJ	Forschungszentrum Jülich (Jülich Research Center)
GAC	Gulfstream aerospace corporation
GALION	GAW aerosol lidar observation network
GAW	Global atmosphere watch
GCM	General circulation model
GCOS	Global climate observing system
GEOSAR	Geostationary search and rescue
GERB	Geostationary Earth radiation budget
GFS	Global forecast system
GHG	Greenhouse gas
GOES-R	Geostationary operational environmental satellite, R-series
GOME	Global Ozone monitoring experiment on the ERS-2 satellite